

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

**(19) World Intellectual Property Organization
International Bureau**



(43) International Publication Date
1 February 2001 (01.02.2001)

PCT

(10) International Publication Number
WO 01/07879 A1

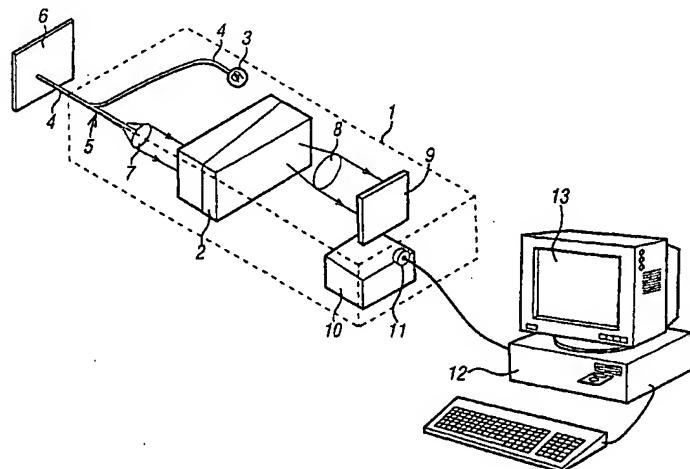
(51) International Patent Classification ⁷ :	G01J 3/453	(GB). HAZELL, Michael, Stuart [GB/GB]; 57 Ainsworth Street, Cambridge CB1 2PF (GB).
(21) International Application Number:	PCT/GB00/02898	(74) Agents: BERESFORD, Keith, Denis, Lewis et al.; Beresford & Co., 2-5 Warwick Court, High Holborn, London WC1R 5DH (GB).
(22) International Filing Date:	27 July 2000 (27.07.2000)	
(25) Filing Language:	English	(81) Designated States (national): CA, US.
(26) Publication Language:	English	(84) Designated States (regional): European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).
(30) Priority Data:		
9917610.9	27 July 1999 (27.07.1999)	GB
(71) Applicant (for all designated States except US): CAMBRIDGE CONSULTANTS LIMITED [GB/GB]		Published: — With international search report. — Before the expiration of the time limit for amending the

Published:

- *With international search report.*
- *Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: FOURIER TRANSFORM SPECTROMETER USING AN OPTICAL BLOCK



WO 01/07879 A1

(57) Abstract: The invention concerns an interferometric optical block for Fourier Transform spectrometers having three planar nominally surfaces (1, 2, BS/C) with the two outer surfaces (1, 2) adapted to act as beam reflectors for internal light and the third surface (BS/C) in operation acting as a beam splitter and beam combiner, the optical block having an input portion by means of which an input beam (3) of light to be analysed can be input so as partially to pass through said third surface (BS/C) to be internally reflected by one of said outer reflectors, and partially to be reflected by said third surface (BS/C) so as then to be internally reflected by the other of said outer reflectors whereby light internally reflected by said outer reflectors is combined at said third surface (BS/C) to produce an exit beam, and wherein said outer surfaces (1, 2) have an inclination with respect to one another so as to make a variation in path lengths in the light forming the exit beam so as to generate an interference fringe field.

13/PYR

1

FOURIER TRANSFORM SPECTROMETER USING AN OPTICAL BLOCK

The present invention concerns interferometers and is particularly concerned with Fourier transform spectrometers. Fourier transform spectroscopy is a well known technique for obtaining the spectra of weak extended sources. It offers throughput and multiplex advantages which can give rise to superior signal-to-noise performance when compared to other methods.

As a result there has been an increasing demand for Fourier transform spectrometers over a wide range of applications including industrial, medical, environmental and consumer applications.

Accordingly there has been a trend of simplifying and ruggedising spectrometer instrumentation to enable it to be used in an extended range of applications. There is however a trade-off between performance and cost associated which tends to limit the range of applications of emerging products.

The present invention is particularly concerned with providing an extremely simple and robust component for a spectrometer as well as improved Fourier Transform Spectrometers.

In one aspect the invention provides optical block in which light to be analysed is internally reflected and combined to produce an interference fringe pattern which can be measured to provide a spectral analysis of the 5 light.

In order that the invention may be more readily understood embodiments thereof, and of the prior art, will now be described by way of example and with reference to the accompanying drawings in which:

10 Figure 1 is a schematic view of a known Michelson interferometer;

Figures 2A and 2B show respectively a fringe function and a spectrum;

15 Figure 3 is a schematic diagram of another known form of interferometer;

Figure 4 shows the basic component of an optical block in accordance with a first embodiment of the present invention;

Figure 5 is similar to Figure 4;

20 Figure 6A and 6B shows steps in the manufacture of the optical block of Figure 5;

Figure 7 is an illustration of a second embodiment

of an optical block in accordance with the present invention;

Figure 8 is similar to Figure 7;

5 Figure 9 is similar to Figure 8 but has certain dimensions exaggerated in the interest of clarity;

Figure 10 is a diagram showing another embodiment of an optical block;

10 Figure 11 is a diagram illustrating a particular practical realisation of an embodiment of an optical block in accordance with the present invention;

Figure 12 is a diagram showing another practical implementation of an optical block in accordance with the present invention;

15 Figure 13 is a diagram illustrating a third practical implementation of an optical block in accordance with the present invention;

Figure 14 is a diagram of spectrometer according to the present invention;

Figure 15 shows two spectral waveforms;

20 Figure 16 is a diagrammatic perspective view of a practical embodiment of a spectrometer;

Figure 17 is a diagrammatic representation of a

variant of the spectrometer of Figure 16;

Figure 18 is a similar view of another variant; and

Figure 19 is a diagram of a particular use of a spectrometer in accordance with the present invention.

5 Referring now to Figure 1 this shows the conventional form of an instrument based on a Michelson interferometer. In this arrangement the interference fringe field formed due to the superposition of the light field U_1 and U_2 reflected respectively from the mirrors M_1 and M_2 via the beam splitter B is incident on a light 10 sensitive detector P. The aperture of this detector is made considerably smaller than the fringe spacing in the plane of detection. The output of this detector thereby defines the interference fringe intensity distribution 15 generated as the mirror M_2 is translated. In Fourier transform spectroscopy this translation is arranged to occur over a distance $\pm D$ about the point where the path length in the translated arm of the interferometer l_2 , matches that of the other arm, l_1 . Figure 2 shows the 20 form of the fringe envelope observed under these conditions where $i(\tau)$ is photo current of the detector P as a function of the mirror displacement $\pm D$. Note

that $i(\tau)$ is proportional to the interference fringe

pattern

$$I_{12} = I_1 + I_2 \times 2\sqrt{I_1 I_2} \gamma(\tau) \frac{4\pi D}{\lambda} \quad (1)$$

where

I_1 = intensity of interfering beam U_1

5 I_2 = intensity of interfering beam U_2

$\gamma(\tau)$ = coherence function of source

τ = D/C

λ = wavelength at light

c = speed of light

10 $\gamma(\tau)$ is equal to the correlation of the two beams of light with a relative delay time $\tau = D/c$ i.e.

$$\gamma(\tau) = f(t)f^*(t+\tau) / \overline{|f(t)|^2} \quad (2)$$

Where

$f(t)$ = defines interfering waveform as function of time,

15 t.

By the Wiener-Khinchin theory, the Fourier transform of $\gamma(\tau)$ is equivalent to the spectral intensity $I(\omega)$. Hence the Fourier transform of the fringe function generated in the specific way described provides a

measure of the spectral distribution of the input light field as is shown schematically in Figure 2. It may be shown that the resolution of this type of spectrometer is given by

5

$$\left(\frac{\delta\lambda}{\lambda}\right)_{\min} = \frac{\lambda}{2D_{\max}} \quad (3)$$

where D_{\max} = maximum amplitude of mirror displacement

Hence a value of $D = 100\mu\text{m}$ will generate a wavelength resolution of under 1nm for $\lambda = 500\text{nm}$.

10

In practice the translation mechanism has to be extremely precise in order to minimise variations in the fringe spacing and vibration across the detector since such variations also cause a modulation of the fringe envelope and introduce errors in the resultant spectrum. This problem is usually minimized by the use of corner cube reflectors but nonetheless these are expensive the instrument still requires a precision positional encoder to define the transform time scale (D/c).

15

20

Moving parts can be eliminated by using the arrangement shown in Figure 3 in which the mirror M_2 is rotated by an angle ϵ about an axis co-incident with the zero-order fringe. A distributed fringe field is then

observed which is imaged in the plane of a pixellated detector array DA by the lens L. The fringe field envelope is then defined by the spatially scanned output of the detector array and is equivalent of that shown in 5 Figure 2 but does not require the translation of a mirror.

Various configurations of interferometer are described in the prior art which are aimed at simplifying and ruggedising the extended fringe field interferometer 10 described above. These include the use of a polarising/birefringent elements to reduce the system to a common path interferometer and a common path, contra propagating three element Sagnac configuration.

Referring now to Figure 4 of the drawings this shows 15 an optical block which comprises two optical elements 1 and 2 which may be fabricated from conventional good quality optical materials such as BK7 glass. The term optical block is used to define the optical components in which the interference fringe field is actually 20 generated.

The optical block shown in Figure 4 has a common central element BS/C which acts as a beam splitter and

combiner and is placed between reflectors R_1 and R_2 . The planes of R_2 , BS/C and R_1 are nominally parallel and R_1 and R_2 separated by a distance of respectively S_1 and S_2 from BS/C. An input beam U_1 of diameter a_1 is incident 5 at angle θ to the surface normal of BS/C such that adjacent beams incident on R_1 and R_2 do not overlap. This requires that $\theta > \sin^{-1}2S_{1,2}/a_1$. Under these conditions it can be seen that two beam interference will occur between 10 various combinations of beam propagating through and exiting from the R_1 , R_2 , BS/C structure (e.g. at d and f).

In the embodiment shown in Figure 4 the interfering beams are reflected once from the outer reflectors. The input beam is split at BS/C into the reflected and transmitted components U_r , U_t respectively. These are in 15 turn reflected from R_1 and R_2 and recombine at B/SC. The interferogram described by equation 1 is generated by arranging for the faces R_1 and R_2 to be inclined at a total angle ϵ with respect to one another. This is more clearly shown in Figure 5 whilst ensuring that the zero 20 order fringe for which $S_1=S_2$ is nominally at the centre of the fringe field. The fringes will localise i.e. have maximum contrast in the plane which the interfering beams

intersect as shown in Figure 5. In practice a lens is used to form an image of the localised fringe field in the plane of the detector array.

A preferred embodiment of this interferometer may be 5 fabricated from a single wedge cut into two wedges along the wedge section as shown in Figure 6. One wedge is then rotated in its plane by 180°C about the cut orientation and its lower face cemented to that of the other prism to form the monolithic element or optical 10 block shown. An input beam 3, output lens 4 and sensor array 5 are also shown. In order to maximise the optical throughput the reflection coefficients of R_1 and R_2 should be as near 1.0 as possible and transmission (t) of reflection (r) coefficients of BS/C should both be equal 15 to 0.5. The sensor array may be any suitable pixellated semiconductor array such as a CCD array.

A key objective in fabrication is to maintain 20 repeatability of fringe geometry. In the above configuration this will depend upon the extent to which the wedge alignment and attachment process causes variations of the orientation of R_1 and R_2 relative to the reference wedge angle $\varepsilon/2$. Sensitivity to alignment

tolerance is relaxed relative to for interferometric precision required in the latter case when the number of reflections at R_1 and R_2 is extended from 1 to 2 as shown in Figure 7. Under these conditions the interfering beams are common to R_1 and R_2 and relative misorientation of the latter do not therefore effect the fringe spacing.

An angular separation between the interfering beams in this dual reflection geometry is formed either by 5
tilting one or a combination of the section of each reflector upon which an individual beam is incident. If 10
the sections A,B,C,D of the reflectors shown in Figure 8 delineate the regions over which there is no overlap of the incident beams they therefore define the sections that may be tilted relative to one another.

Figures 9 and 10 show respectively the arrangement 15
in which section A and sections A&B are tilted. Here it will be noted that the only requirement when two sections are tilted is that the tilts be in an opposite sense so that the angular displacement created by the first is not 20
compensated by the second. The position of the zero order fringe will also be a function of the relative tilt of the two reflectors since this will define the point

for which the path lengths of the two interfering beams are equal. In the case of Figure 9 (A tilted only) the zero fringe will occur at the extreme edge of the interference field. This position will shift towards the 5 centre as B is tilted in the opposite sense (Figure 10) and will be at the centre of the fringe field when the tilts of the two mirrors are equal. Note that a lateral shift of the dual angle reflector relative to the flat provides a means of fine tuning the position of the zero 10 order fringe.

For one class of preferred configuration the tilts are confined to the R_1 element so that the BS/C and R_2 functions may be combined on a single optical flat with parallel faces. Figure 11 illustrates how the optical 15 block is formed by such an optical flat located on an element M which incorporate the symmetrically tilted reflector R_1 . In practice M could be a precision moulded component and the optical block assembled by inserting the flat F in the pre-moulded location. This procedure is compatible with low cost components and manufacture 20 since as has been noted above, this configuration of the optical block is not dependent on the precision location

of R_1 with respect to R_2 .

Figure 11 also shows the additional components the system consisting of an extended source S (which may in practice consist at a large core optical fibre),
5 collimating/focussing input lens L_1 , output fringe and field imaging element L_0 and detector array A. These elements will, in general, be required for all geometrics at the interferometer.

Figure 12 shows an alternative way of manufacturing
10 the optical block in which the optical flat G is attached directly to the dual angle prism H. This arrangement is particularly robust and could, for example, be manufactured from low expansion glass to enable operation at elevated temperatures. Figure 12 shows the same basic
15 design in which all faces are mutually tilted. This configuration could be manufactured by slicing and rejoining a dual angle prism in accordance with the principle indicated in Figure 7 for a single angle (i.e. wedge) prism.

20 In order to maximise the optical throughput the outer reflection R_1 and R_2 should have a coefficient of reflectivity as near to unity as possible and the

reflection (r) and transmission coefficients r,t at BS/C should be respectively .33 and .66. These coefficients should apply over the spectral range of operation.

Figure 14 shows schematically a typical practical 5 implementation of the optical blocks just described in an interferometer. Here light from a source S is coupled to a region of test T via a beam splitter B.

In this configuration T may be a sample for which it is required to measure the spectral reflectivity. 10 Alternatively T may be a passive reflector and the spectral transmission of the medium between the light delivery element and T measured. In either case light is coupled into the interferometer I via the current lens L_i and imaged onto the detection array DA by the output lens L_o . In a preferred configuration all of the elements external to the interferometer may in practice be integrated with the structure at the optical block of the interferometer by combining, for example, moulded light guides and lenses with the reflective elements. The 15 output of the detection array can be Fourier transform analysed in a well known manner by a suitable processor 20 PC for display or printing.

Figure 15 is an example of a preliminary experimental result which shows the spectrum of the same source measured using a calibrated spectrometer and that obtained using a laboratory version of the dual 5 reflection spectrometer described above.

It will be appreciated that the optical blocks just described are compatible with robust monolithic fabrication of the two elements. With respect to the current state of the art it therefore reduces cost by 10 eliminating the need for specialised components whilst simplifying manufacture by virtue of the reduction in component number.

Referring now to Figure 16 this shows a practical embodiment of an interferometer incorporating an optical 15 block of the type previously described. Thus a main housing 1 houses the optical block 2. An LED 3 supplies light of a predetermined wavelength to a optical fibre 4 which is bifurcated at 5 so as to direct light reflected from a test surface 6 onto a lens 7 which is arranged to 20 input the reflected light to the optical block 2. Light issuing from the optical block 2 is collected by a lens 8 and focussed onto a photosensitive array 9, for example

composed of CCD sensors. A unit 10 houses power for the LED and the CCD array and also provides in the form of a microprocessor output signals for controlling the sensor array in order to enable an output to be sent via an output port 11 to a suitable processor 12 where the results of the spectroscopy can be analysed and displayed on the screen 13 of the processor.

As will be appreciated the entire arrangement of the spectrometer can be encapsulated in a plastics material so that the components are rigidly held in the correct relationship and that the spectrometer is extremely resistant to shock and other adverse conditions.

Turning now to Figure 17 of the accompanying drawings, this discloses one particular way in which spectrometers according to the present invention can be utilised. It will be appreciated that Fourier transform spectrometers do not require small input apertures as in the case for dispersive grating devices for which narrow input slips, typically less than 0.1mm are required. With the embodiments described good results can be achieved with 2mm diameter input fibre bundles. This means that the embodiment shown in Figure 16 may be used

to multiplex a number of light sources and points of measurement of the surface D into a single spectrometer. Thus in Figure 16 the single LED may be replaced by a number of separate light sources all under the control of the microprocessor housed in unit 10. Similarly the optical fibre 4 is replaced by a plurality of parallel optical fibres each coupled to an individual light source and instead of a single output as shown in the figure, each of these light fibres have their outputs spread across at least one dimension of the target surface 6. Similarly the input to the lens 7 would be from the bundle of fibres as bifurcated at 5.

This arrangement is shown diagrammatically in Figure 17. In Figure 17 a number of light sources S₁ to S_n and an equivalent number of points of measurement of a surface D, P₁ to P_n, are coupled to a single spectrometer. Here light from the sources is first coupled into the fibres F₁ to F_n and then to directional 3dB (50:50) or bifurcated couplers C₁ to C_n. The light is then coupled out of the fibres onto the object D. The light scattered/reflected from the points of measurement P₁ to P_n in the object is coupled to the spectrometer via

the 3dB couplers and the output fibres F1 to Fn. As discussed S1 to Sn may be time multiplexed so that only one measurement point P is illuminated at a given time. Under these conditions a spectral image of the surface D 5 may be synthesised from the time demultiplexed output of the spectrometer by the processor shown at 12.

The above arrangement can be configured in the transmissive mode using the fibre arrangement shown in Figure 17. A similar dual fibre arrangement can also be 10 used for reflective measurements.

Referring now to Figure 18 this shows an embodiment in which a spectrometer in accordance with the present invention is combined with a remote sensing head 20 of rugged construction and receives light from a short 15 coherence source 21 through a semi-reflective mirror 22 and an optical fibre link 23. After reflection in the sensing head 20 light is returned through the optical fibre link 23 to the mirror 22 and reflected into a Fourier transform spectrometer which can be identical to the spectrometer shown in Figure 16 and which is, 20 therefore, in accordance with the present invention.

The purpose of the arrangement shown in Figure 18 is

to separate the sensing head from the processing interferometer and to provide a sensing head which does not contain any active optical or electronic components but contains only passive optical elements which may accordingly be highly resistant to hostile environments.

5 Thus the sensing head 20 comprises a beam splitter 25, a fixed reference mirror 26 and a movable mirror 214, the position of which changes in response to the measureand. The optical path lengths between the beam splitter 25 and 10 the mirrors 26 and 27 are arranged to be different and the difference between these two path lengths is arranged to be substantially greater than the coherence length of source 21. As a result of this when the light reflected by the two mirrors 26 and 27 is recombined in the beam 15 splitter 25, interference fringes will not be apparent in the combined beam supplied back to the optical fibre link 23. Thus the spectrometer 24 is arranged to compensate for the path length difference introduced in the remote sensing head 20 and generate a fringe field for which 20 absolute phase changes occurring at the sensor can be determined.

It will be appreciated that as with the embodiment

previously described a plurality of remote sensing heads can be used each associated with an individual coherent light source and the outputs of the various sensing heads combined into an optical fibre bundle for transmission to 5 the Fourier transform spectrometer 24. Once again it is possible to control the lighting pattern of the coherent light sources so that the signals received by the spectrometer from the light sources and sensing heads are temporarily spaced for subsequent analysis by a computer 10 system similar to that shown in Figure 16.

It is of course possible that either an optical block similar to any one of those described in the preceding specification could be employed in the remote sensing head or heads of the embodiment just described.

CLAIMS:

1. An interferometric optical block having three planar nominally parallel surfaces with the two outer surfaces adapted to act as beam reflectors for internal light and
5 the third surface in operation acting as a beam splitter and beam combiner, the optical block having an input portion by means of which an input beam of light to be analysed can be input so as partially to pass through said third surface to be internally reflected by one of
10 said outer reflectors, and partially to be reflected by said third surface so as then to be internally reflected by the other of said outer reflectors whereby light internally reflected by said outer reflectors is combined at said third surface to produce an exit beam, and
15 wherein said outer surfaces have an inclination with respect to one another so as to make a variation in path lengths in the light forming the exit beam so as to generate an interference fringe field.

20 2. An optical block in accordance with claim 1 in which the exit beam results from the interference of the beams transmitted and reflected from the beam splitter/combiner

that have in operation each undergone a single reflection at the outer reflectors.

3. An optical block in accordance with claims 1 or 2
5 which has been fabricated by cutting a single wedge element parallel to the wedge section to create two identical wedges and with one such wedge so cut rotated 180°, the lower face of said one wedge being secured to the other wedge to form a monolithic element, the
10 adjacent faces of the wedges forming said third surface.

4. An optical block in accordance with claim 1 in which the exit beam in operation results from the interference of beams combined at the beam splitter/combiner which
15 have undergone two reflections at the outer reflectors.

5. An optical block in accordance with any preceding claim in which the beam splitter/combiner and one reflector are formed by an optical flat with parallel
20 faces and the other reflector is provided by a single unit comprising the inclined mirror or mirrors and an integral location for the optical flat.

6. An optical block in accordance with any one of claims 1 to 4 in which the beam splitter/combiner and one reflector are formed by an optical flat with parallel faces and the other reflector by a solid prism with one plane face and an inclined second face, the block having been assembled by attaching the plane face of the solid prism to the plane beam splitter/combiner face of the optical flat.

10 7. An optical block in accordance with any one of claims 1 and 4 fabricated from two identical solid dual angle prisms where the plane faces are attached to form the beam splitter combiner and the outer identical and mutually inclined faces form the reflectors.

15

8. An optical block in accordance with claim 7 in which the prisms have been obtained by cutting in two a single dual angle prism in a plane parallel to the dual angle section.

20

9. An optical block according to any one of the preceding claims wherein in order to maximise optical

throughput over the spectral range of operation said beam splitter/combiner and reflector surfaces are coated with a coating such that the reflectivity coefficient of the reflectors is approximately 1.0 and the transmission coefficient and reflection coefficient being respectively 0.5 and 0.5 for the single reflection configuration and 5 .66 and .33 for the dual reflection configuration.

10. An optical block in accordance with any preceding 10 claim including a lightguide or optical fibre associated with said input portion.

11. A Fourier Transform Spectrometer comprising an optical block as claimed in any one of the preceding 15 claims, a light source for directing light to be interferometrically analysed to the input portion of said block so that the light beams incident on the reflectors and the beam splitter/combiner do not overlap, and a light sensor array for detecting the pattern of the 20 fringe field, the fringe field having a multiplicity of fringes about a zero order fringe so that a Fourier transform of said fringe pattern corresponds to the

spectral distribution of the illumination source.

12. A spectrometer according to claim 11, comprising a
lens system adapted to form an image of the optimum
5 contrast fringe field as localised on a plane relative to
the interferometer onto said sensor array, and wherein
said sensor array comprising is a pixellated semi-
conductor array.

10 13. A spectrometer according to claim 12 and including
electronic processor adapted to generate the Fourier
transform of the electrical signal generated by said
array so as to measure the spectral distribution of the
input light.

15

14. A spectrometer according to any of claims 11 to 13
comprising means for coupling light to and from the
measurement zone, imaging light into interferometer and
imaging the fringe field light out of optical block onto
20 the detector array form an integral element of the
interferometer.

15. A spectrometer according to any one of claims 11 to
14, and comprising a plurality of light sources each
associated with an optical fibre, and wherein each
optical fibre is adapted to direct light from its
5 associated light source either onto or through a test
medium, and wherein light reflected by, scattered from or
transmitted through the test medium is, in operation of
the spectrometer, coupled to said light sensor.

10 16. A spectrometer according to claim 16, wherein the
spectrometer includes means whereby the light sources can
be illuminated at different intervals.

15 17. A spectrometer according to any one of claims 11 to
16, in combination with a remote sensor.

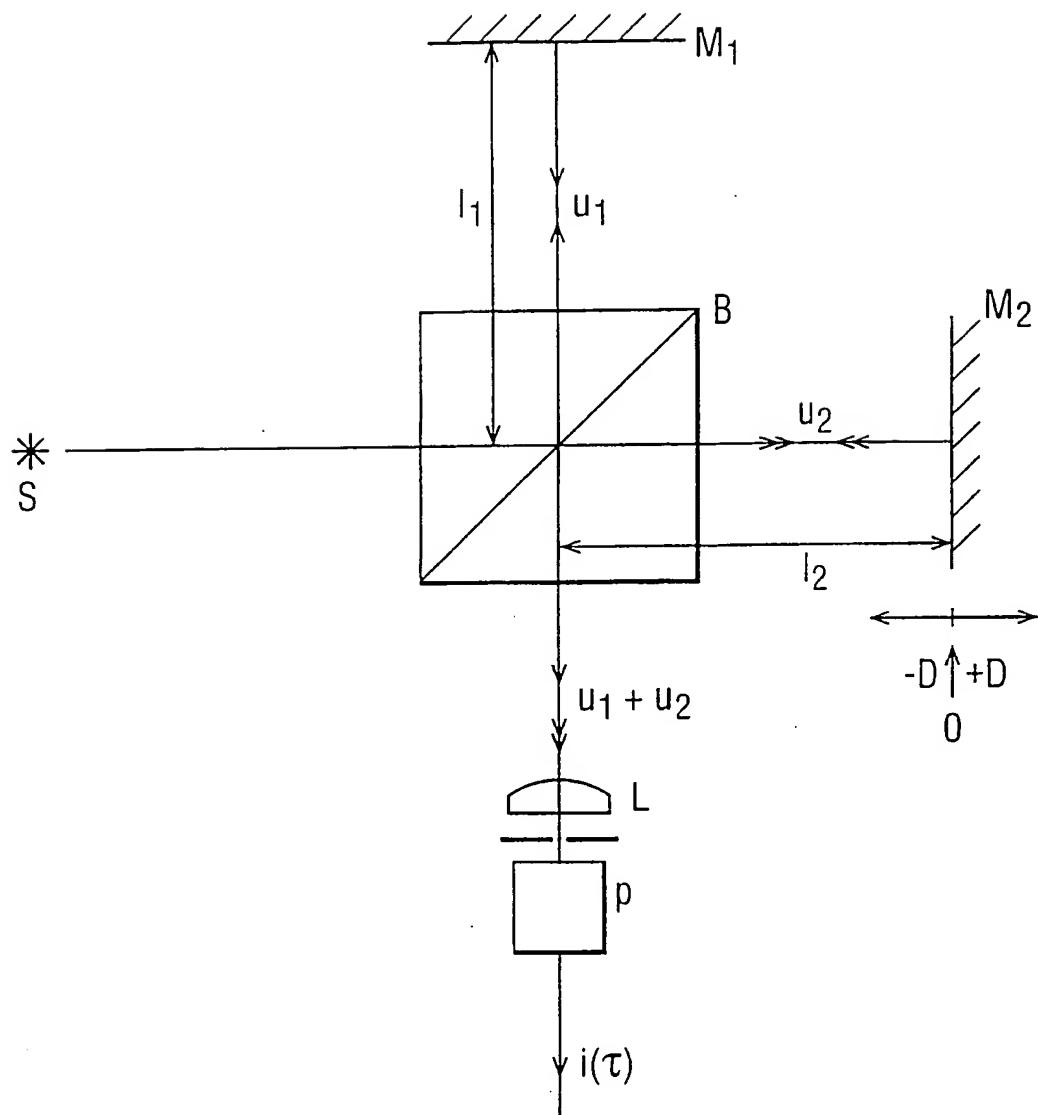
18. A spectrometer according to claim 17, wherein the
remote sensor is adapted to receive light from a
coherence source through a semi-reflective mirror and
20 includes means for separating light received from the
coherence light source into two paths the lengths of
which differ by a distance greater than the coherence

length of the coherence light source.

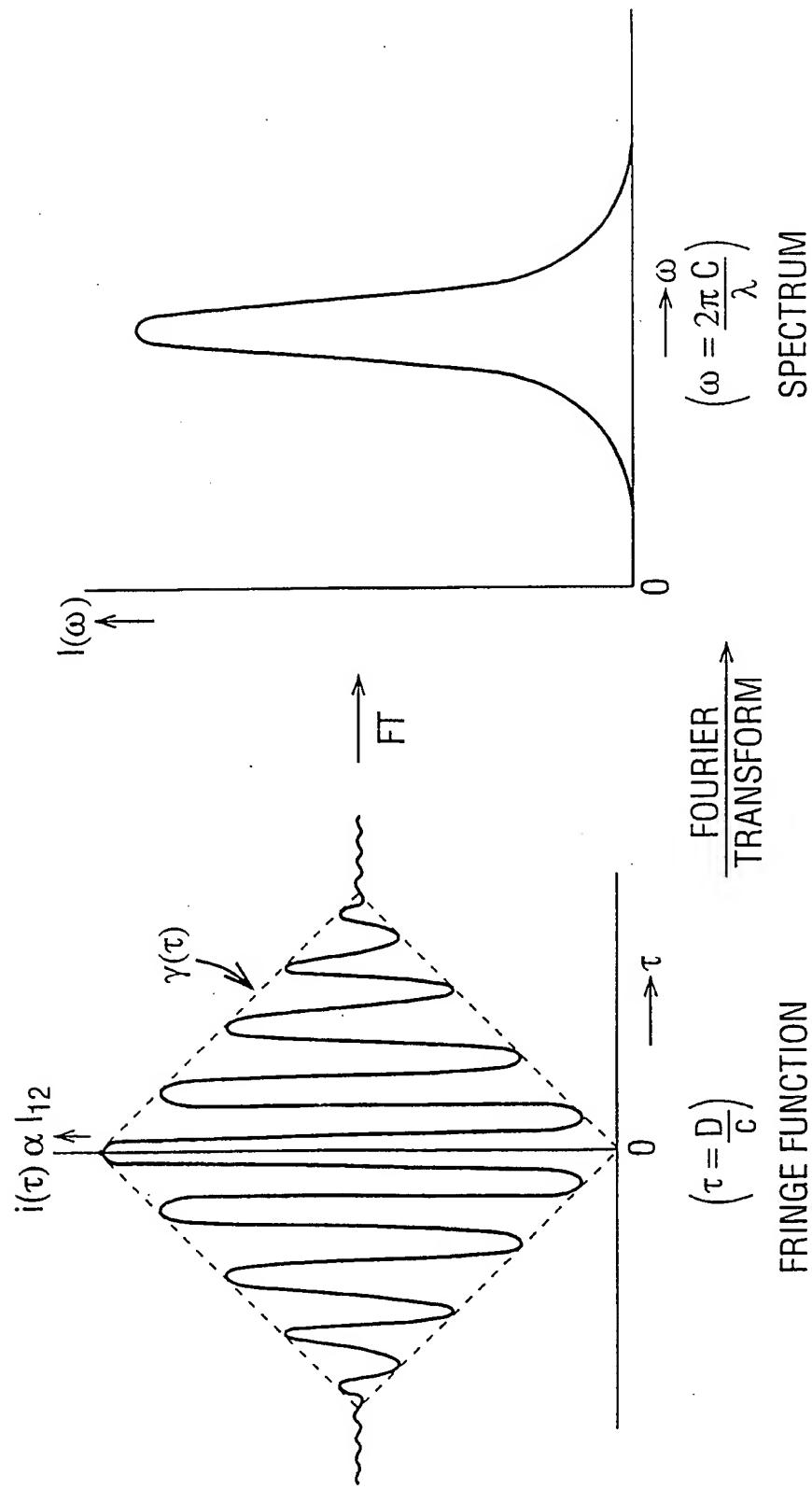
19. A spectrometer according to claim 18, wherein the
sensing head comprises a beam splitter, a fixed reference
5 mirror and a movable mirror the position of which changes
in response to a measurand.

1/13

FIG. 1

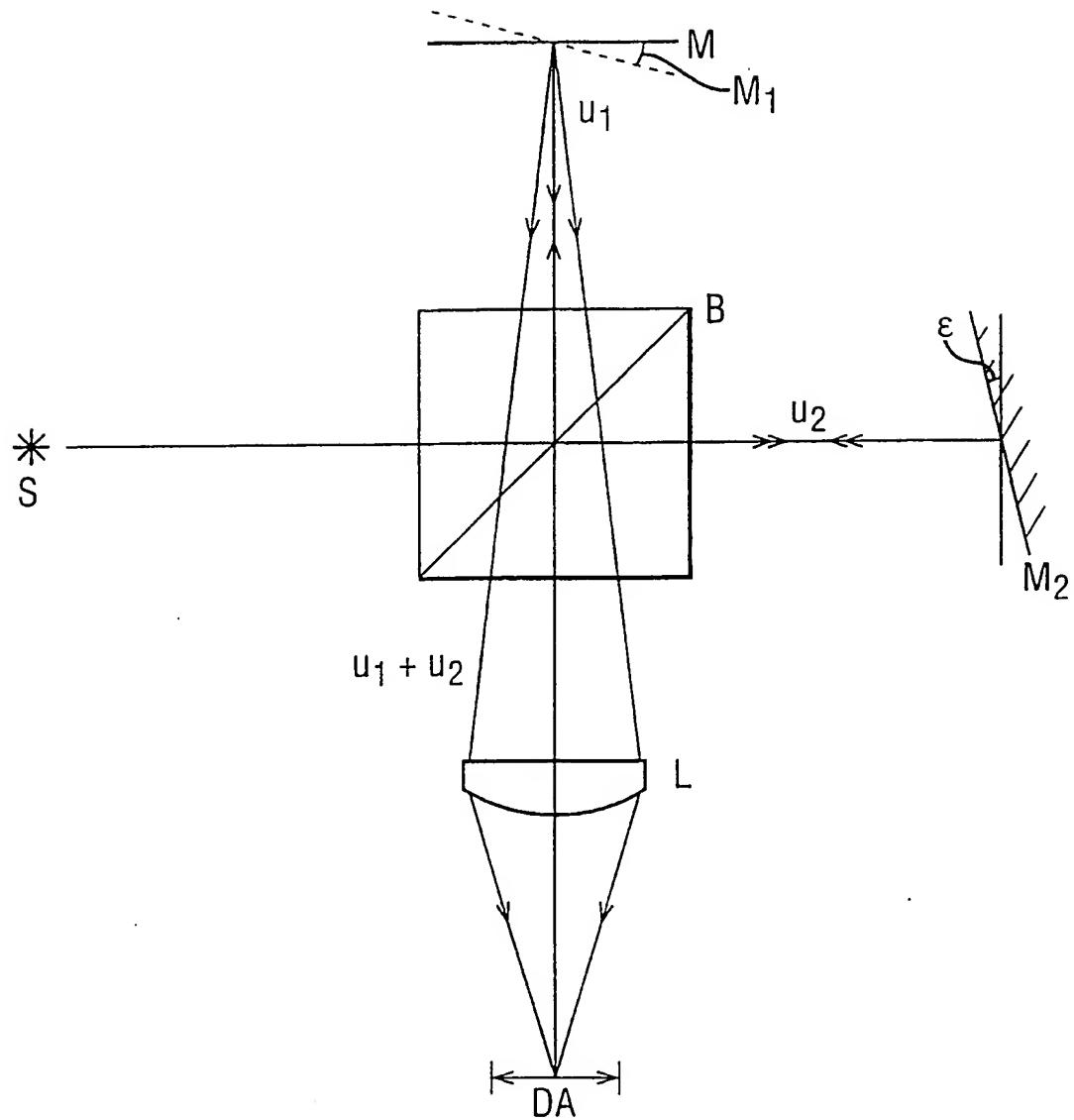


2/13

FIG. 2(A)
FIG. 2(B)

3/13

FIG. 3



4/13

FIG. 4

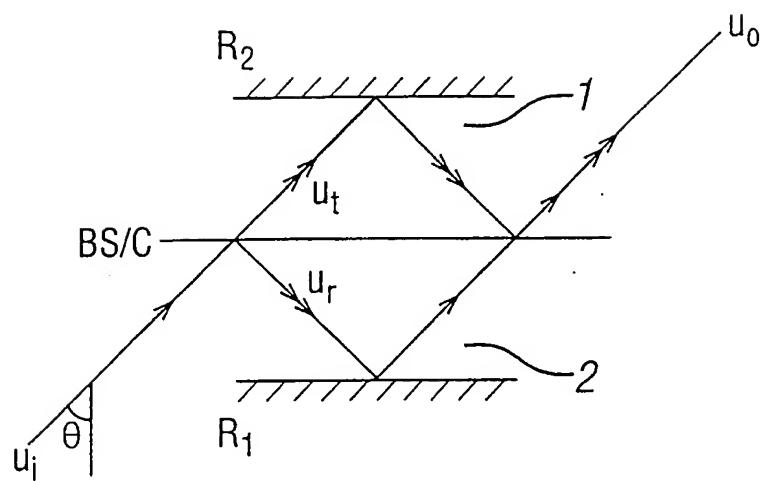
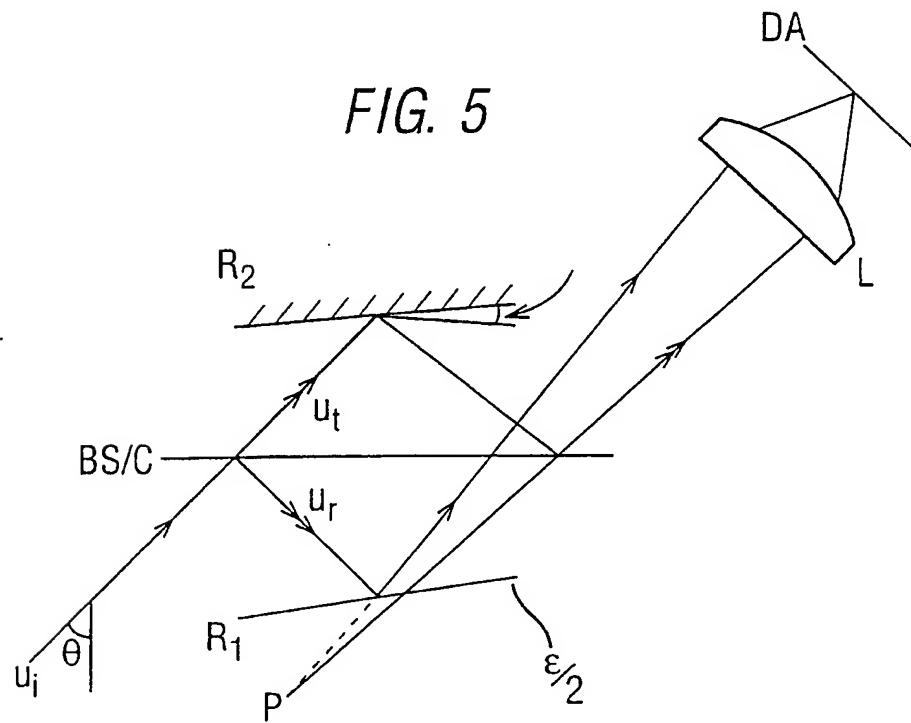


FIG. 5



5/13

FIG. 6(A)

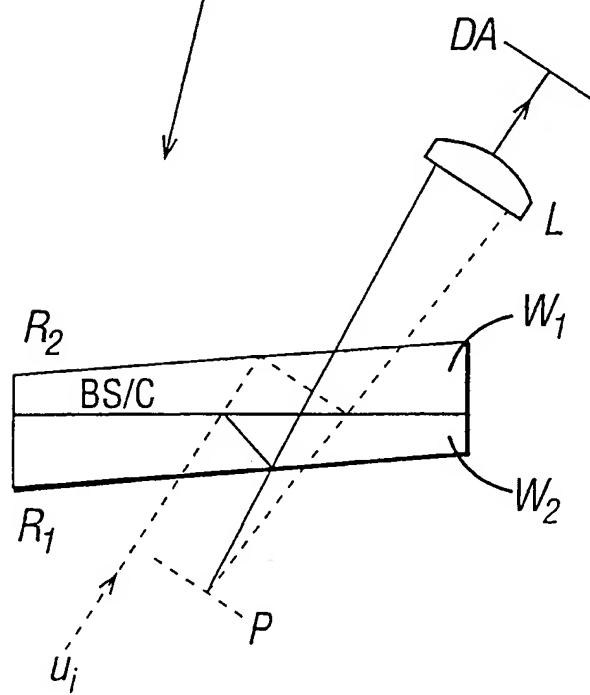
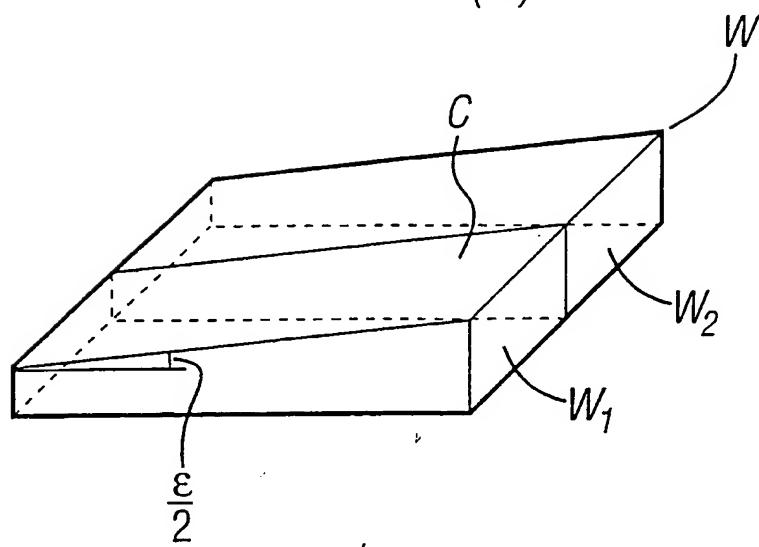


FIG. 6(B)

6/13

FIG. 7

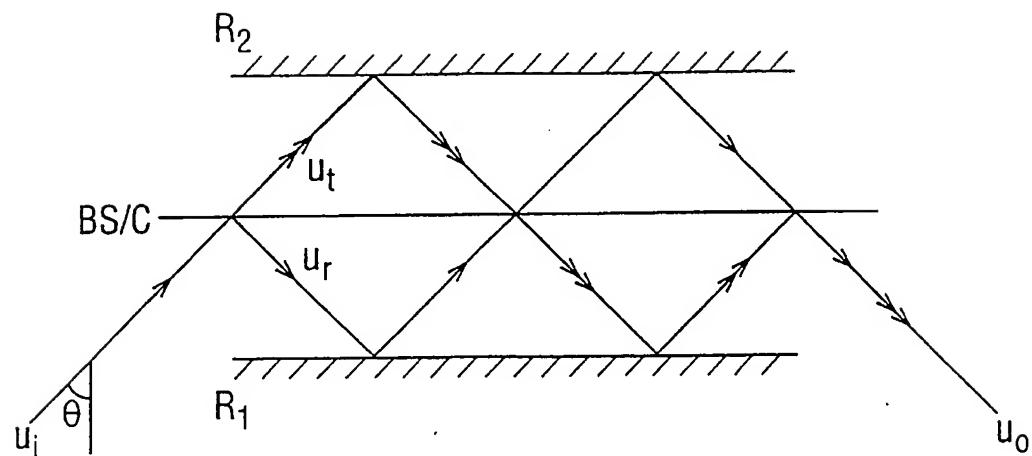
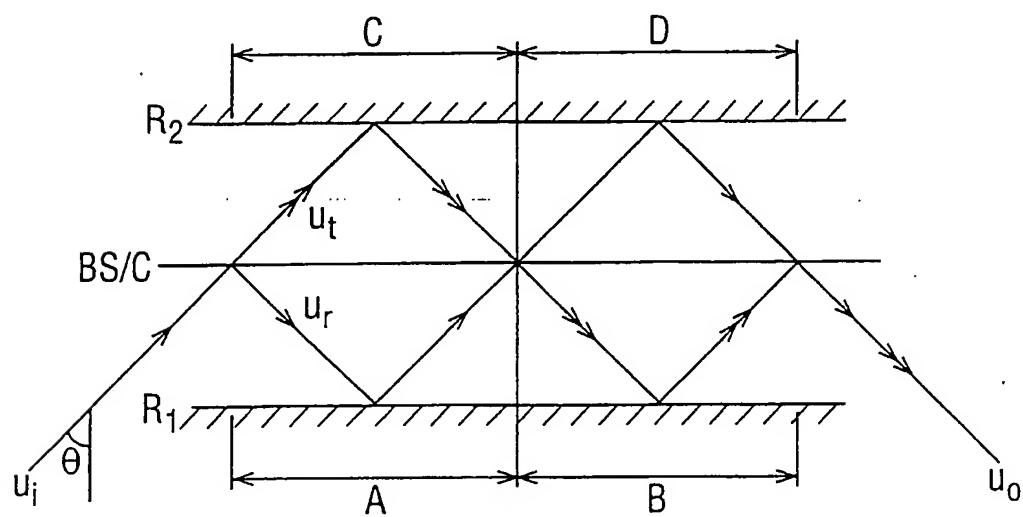


FIG. 8



7/13

FIG. 9

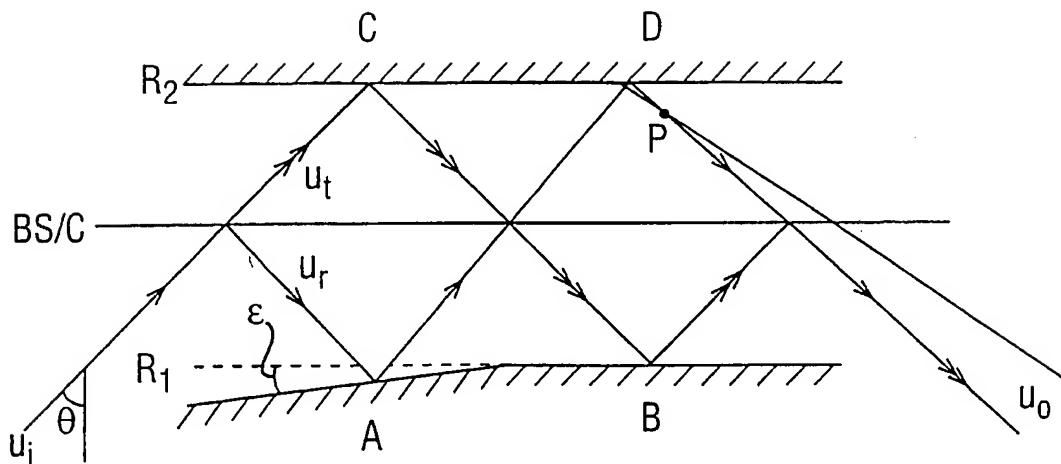
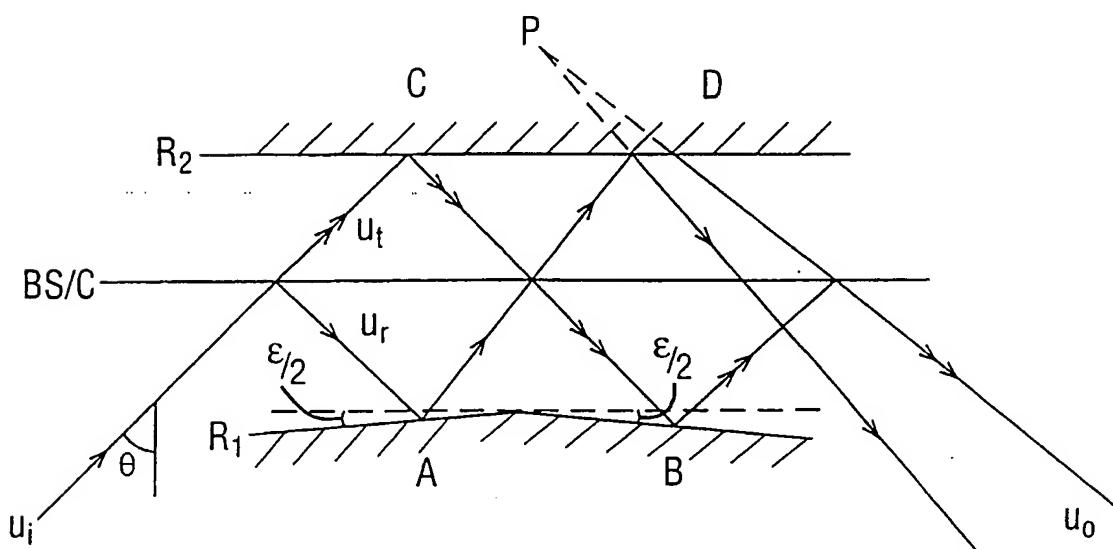


FIG. 10



8/13

FIG. 11

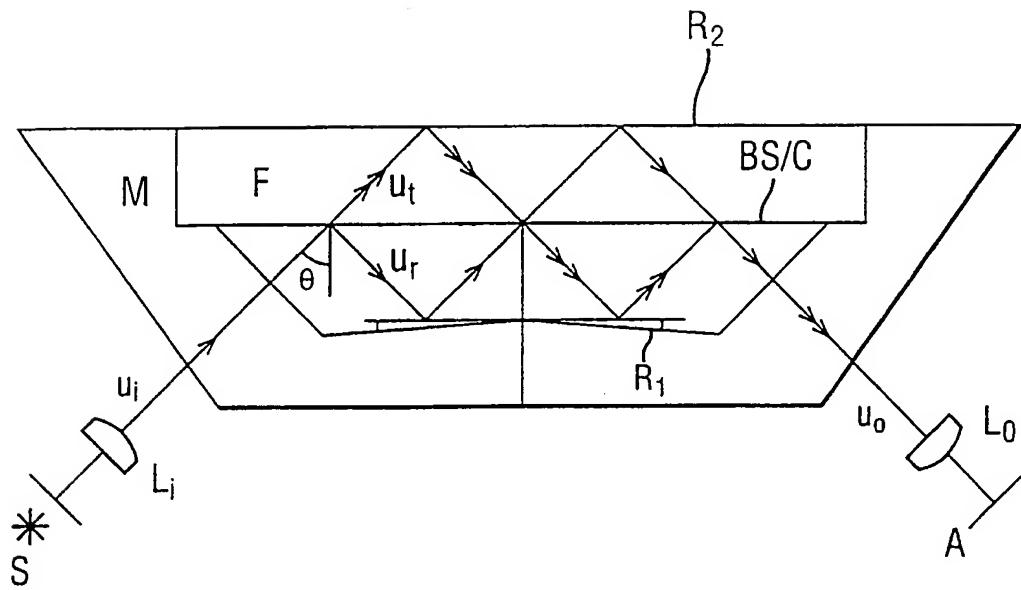
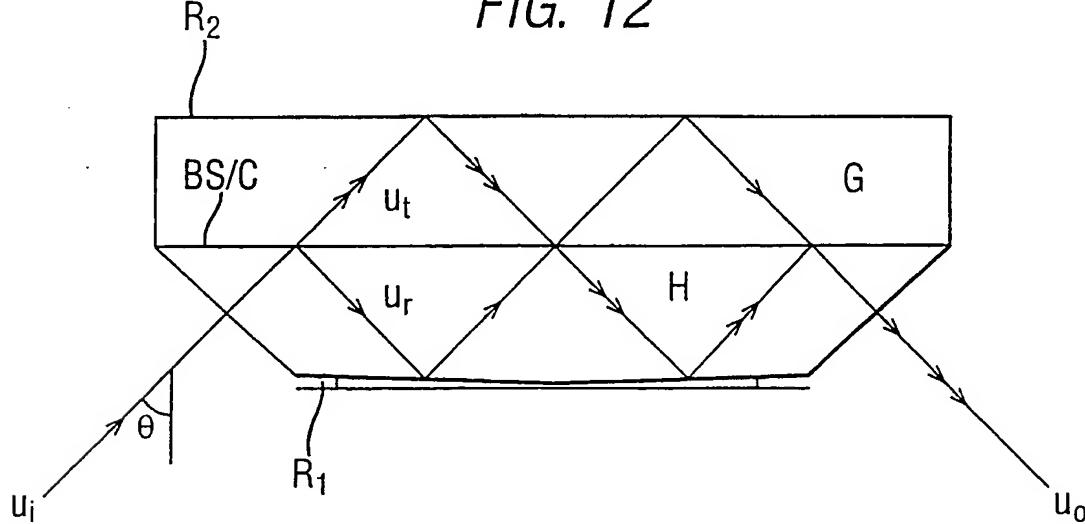


FIG. 12



9/13

FIG. 13

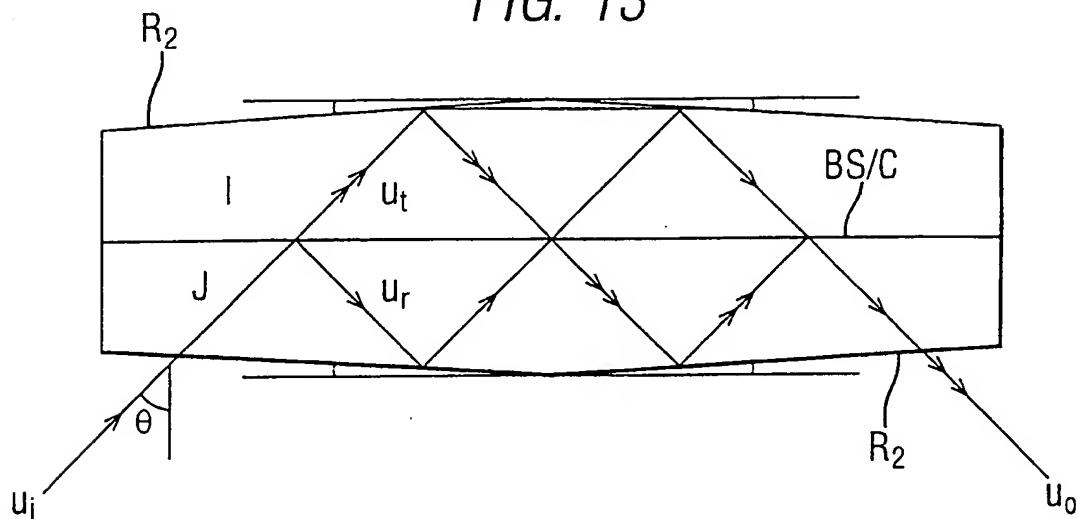
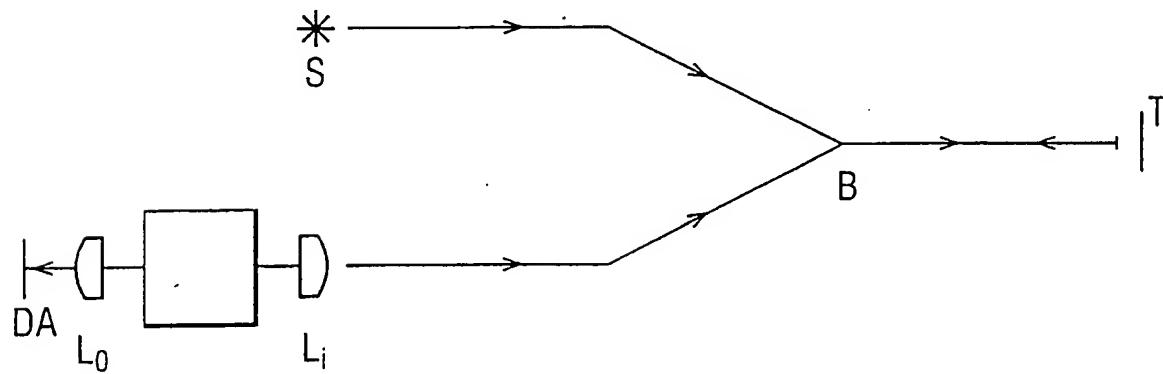


FIG. 14



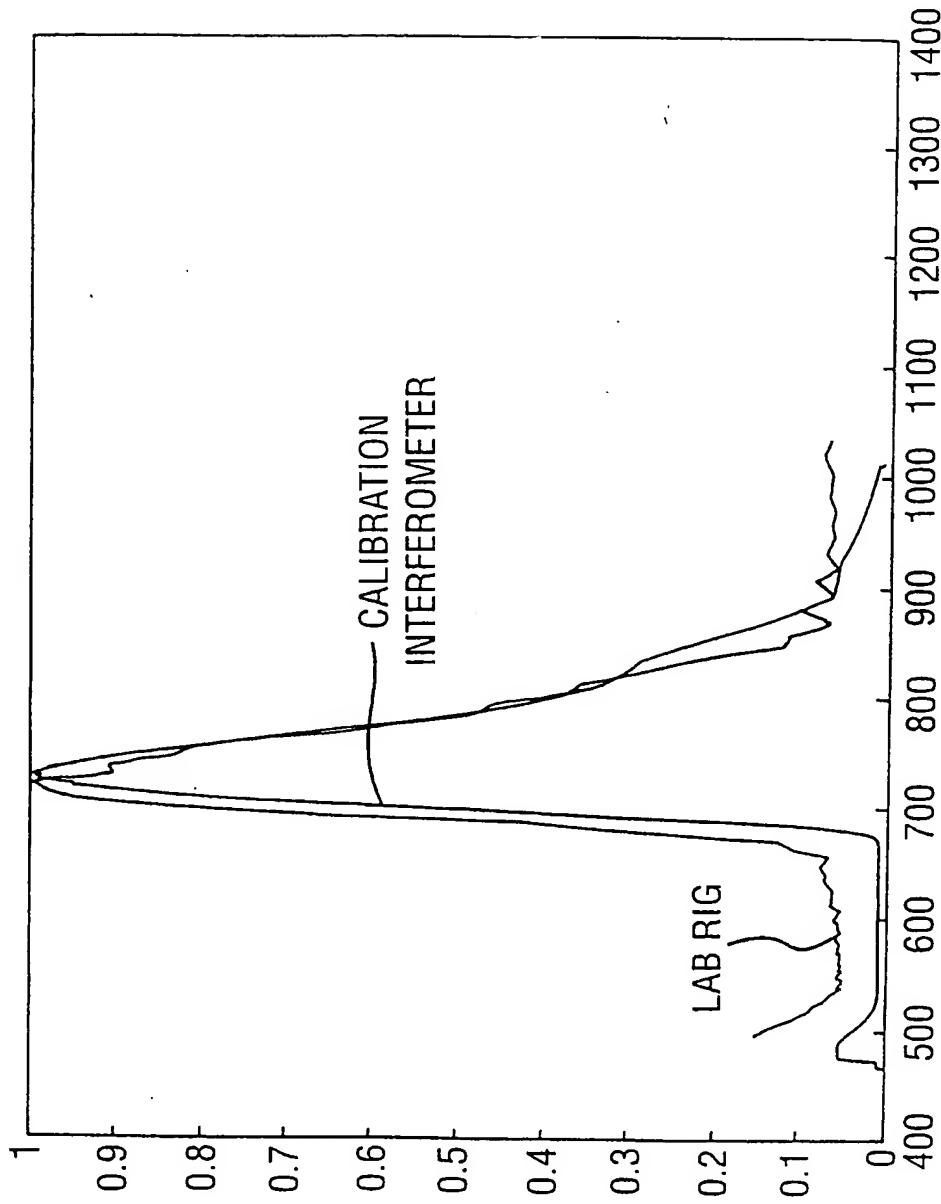
10/031948

WO 01/07879

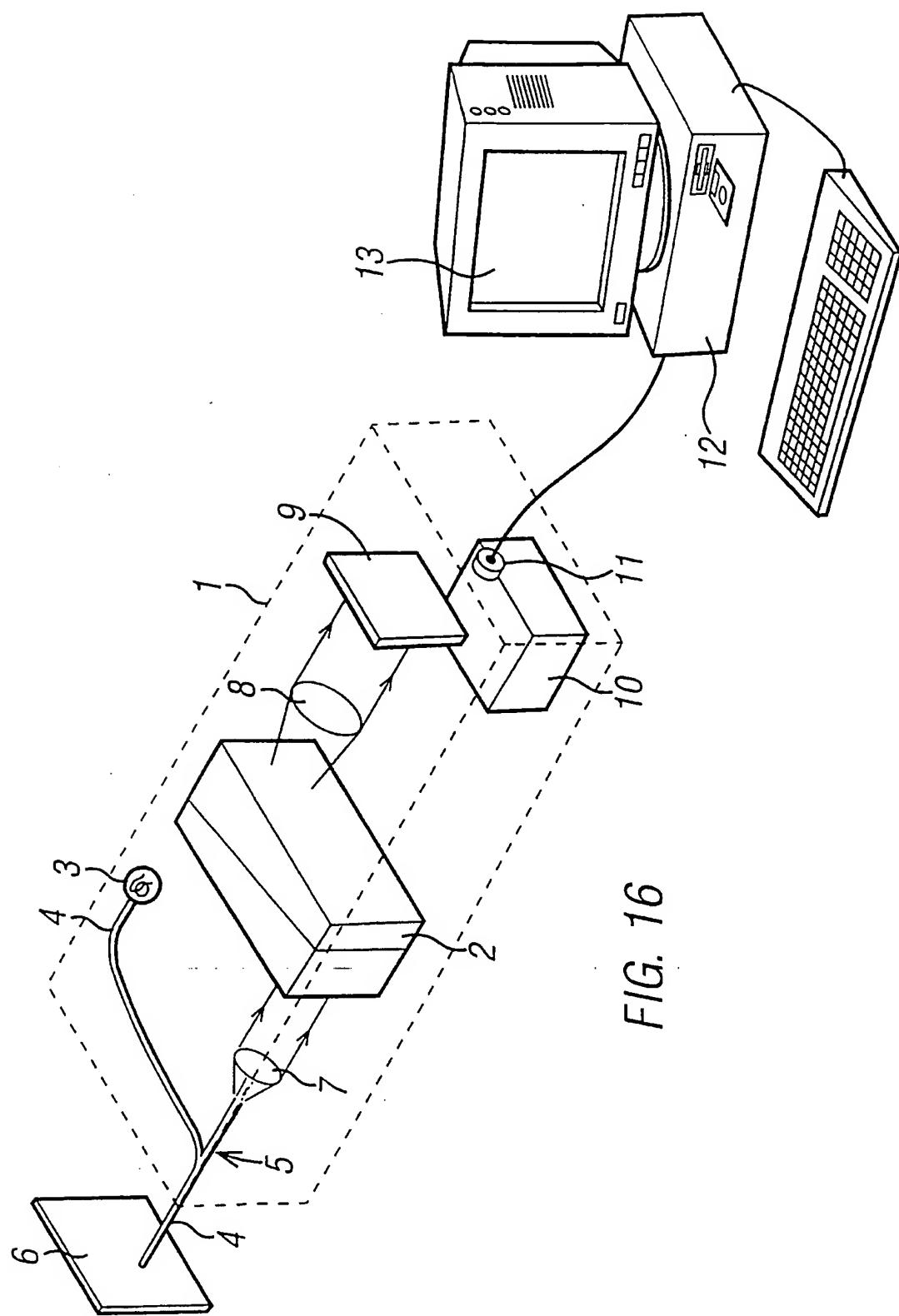
PCT/GB00/02898

10/13

FIG. 15
ROYAL BLUE (FILTER 007)



11/13



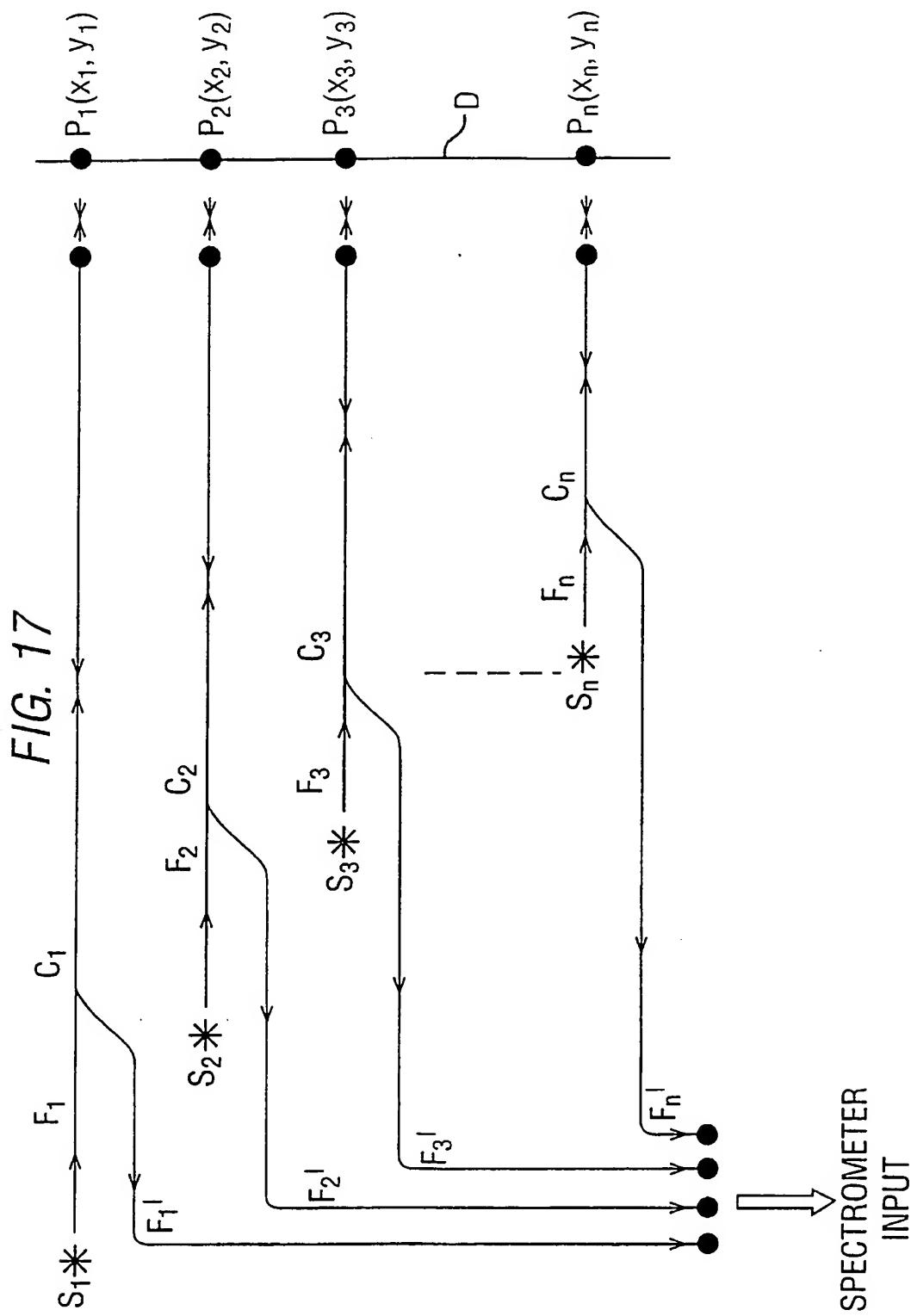
SUBSTITUTE SHEET (RULE 26)

10/031948

WO 01/07879

PCT/GB00/02898

12/13



SUBSTITUTE SHEET (RULE 26)

13/13

FIG. 18

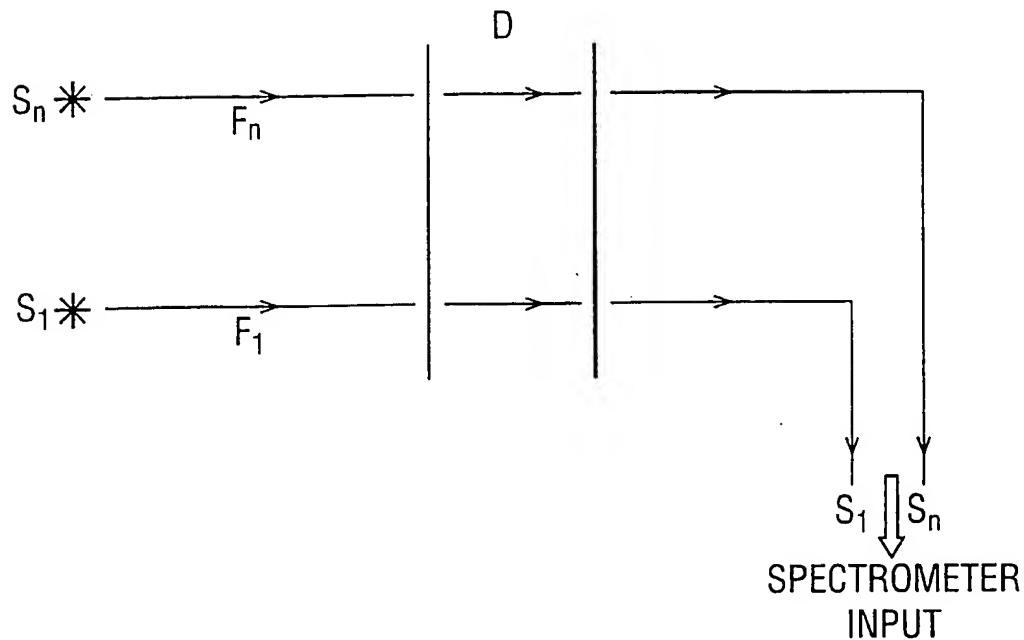
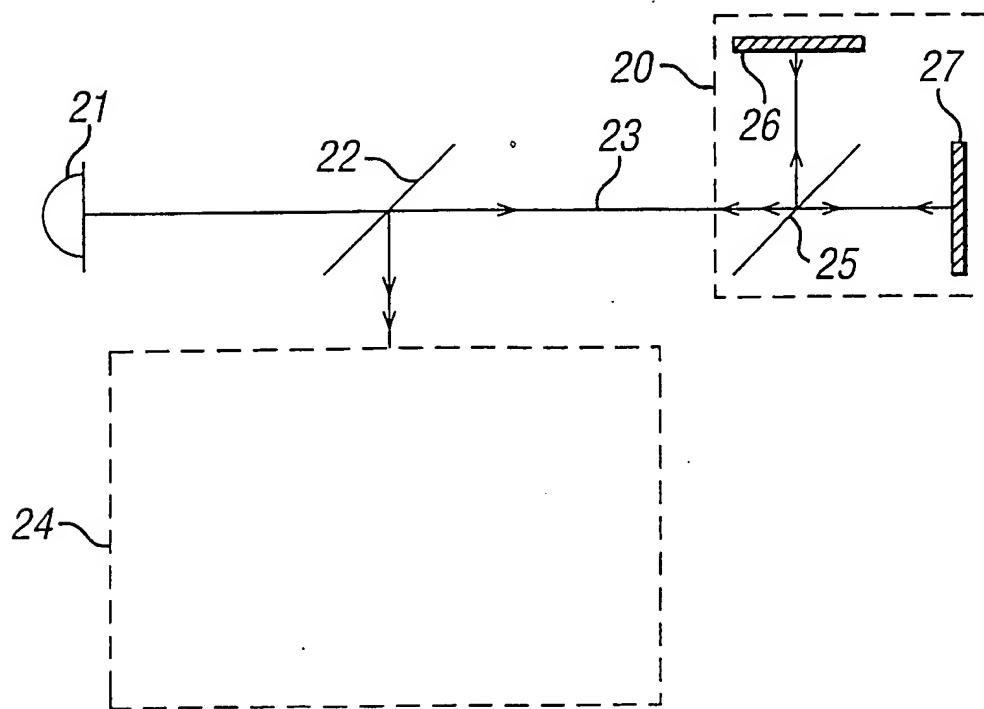


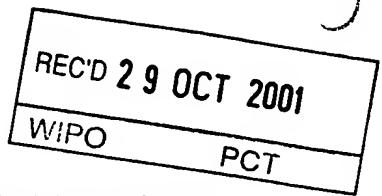
FIG. 19



SUBSTITUTE SHEET (RULE 26)

CLAIMS:

1. An interferometric optical block having three planar nominally parallel surfaces with the two outer surfaces adapted to act as beam reflectors for internal light and the third surface in operation acting as a beam splitter and beam combiner, the optical block having an input portion by means of which an input beam of light to be analysed can be input so as partially to pass through said third surface to be internally reflected by one of said outer reflectors, and partially to be reflected by said third surface so as then to be internally reflected by the other of said outer reflectors whereby light internally reflected by said outer reflectors is combined at said third surface to produce an exit beam, and wherein said outer surfaces have an inclination with respect to one another so as to make a variation in path lengths in the light forming the exit beam so as to generate an interference fringe field.
2. An optical block in accordance with claim 1 in which the exit beam results from the interference of the beams transmitted and reflected from the beam splitter/combiner



INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference IM/5314299	FOR FURTHER ACTION		See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/GB00/02898	International filing date (day/month/year) 27/07/2000	Priority date (day/month/year) 27/07/1999	
International Patent Classification (IPC) or national classification and IPC G01J3/453			
<p>Applicant CAMBRIDGE CONSULTANTS LIMITED</p>			
<p>1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.</p> <p>2. This REPORT consists of a total of 5 sheets, including this cover sheet.</p> <p><input checked="" type="checkbox"/> This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).</p> <p>These annexes consist of a total of 1 sheets.</p>			
<p>3. This report contains indications relating to the following items:</p> <ul style="list-style-type: none"> I <input checked="" type="checkbox"/> Basis of the report II <input type="checkbox"/> Priority III <input type="checkbox"/> Non-establishment of opinion with regard to novelty, inventive step and industrial applicability IV <input type="checkbox"/> Lack of unity of invention V <input checked="" type="checkbox"/> Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement VI <input type="checkbox"/> Certain documents cited VII <input checked="" type="checkbox"/> Certain defects in the international application VIII <input checked="" type="checkbox"/> Certain observations on the international application 			

Date of submission of the demand 27/02/2001	Date of completion of this report 25.10.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Schmidt, C. Telephone No. +49 89 2399 2254



INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/02898

I. Basis of the report

1. With regard to the **elements** of the international application (*Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17)*):

Description, pages:

1-19 as originally filed

Claims, No.:

2-19 as originally filed

1 as received on 10/10/2001 with letter of 10/10/2001

Drawings, sheets:

1/13-13/13 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- the language of publication of the international application (under Rule 48.3(b)).
- the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- contained in the international application in written form.
- filed together with the international application in computer readable form.
- furnished subsequently to this Authority in written form.
- furnished subsequently to this Authority in computer readable form.
- The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/02898

the description, pages:

the claims, Nos.:

the drawings, sheets:

5. This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N) Yes: Claims 1 - 19
 No: Claims

Inventive step (IS) Yes: Claims 1 - 19
 No: Claims

Industrial applicability (IA) Yes: Claims 1 - 19
 No: Claims

2. Citations and explanations see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

**INTERNATIONAL PRELIMINARY
EXAMINATION REPORT - SEPARATE SHEET**

International application No. PCT/GB00/02898

CITED DOCUMENTS

D1: DE 197 49 377 A1 (MAX-PLANCK-GESELLSCHAFT zur Förderung der Wissenschaften e.V.) 02 June 1999.

SECTION V

1. Document D1, which is considered as the closest prior art, discloses (cf. figure 2) an interferometric optical block having three planar nominally parallel surfaces (23, 24, 26) with the two outer surfaces adapted to act as reflectors (24, 26) and the third surface (23) to act as a beam splitter and recombiner. The optical block has an input portion (where light beam 21 enters) whereby the entering light beam passes partially through the third surface to be internally reflected on the reflector (24) and partially is reflected by the third surface (23) to be internally reflected by the other reflector (26). The beams are then recombined at the third surface to produce an exit beam (22). The outer surfaces have an inclination with respect to each other (as can be seen in the figure).
2. The present invention, as defined in claim 1, differs from the device of D1 in that the inclinations of the outer surfaces are asymmetric with respect to said third surface. Claim 1 is thus novel.
3. According to the present invention a shear between the interfering wave fronts is introduced which results in the generation of a linear fringe field distributed about the zero-order fringe. This is not hinted at in the cited prior art. In particular, D1 defines a rotating arrangement whereas the present invention is used stationary. An inventive step over the cited prior art is therefore acknowledged.
4. The dependent claims 2 to 19 include all the features of claim 1 upon which they depend and are thus also considered novel and inventive.
5. Industrial applicability is given in the field of **Fourier transform spectrometers**.

**INTERNATIONAL PRELIMINARY
EXAMINATION REPORT - SEPARATE SHEET**

International application No. PCT/GB00/02898

SECTION VII

The claims should have been drafted in accordance with Rule 6.3 b (two-part form) and 6.2 b (reference signs in claims) PCT, taking into consideration the document D1 above. This document should also have been acknowledged in the introductory part of the description pursuant to Rule 5.1 a) ii) PCT.

SECTION VIII

1. In claim 1 the wording "so as to make a variation in optical path length" should be inserted on line 17 after "one another" since this is an essential feature (cf. also original claim 1). Further, the wording "are asymmetric" should be clarified, ie it should be clear in which respect they are asymmetric (eg with respect to the inclinations).
2. In claim 6, line 6, the word "fact" should probably read "face".
3. In claim 12, line 5 the word "comprising" does not make sense.
4. In claim 14 the last two lines are not clear, there seems to be a grammatical error regarding the back references.

CLAIMS:

1. An interferometric optical block having three planar nominally parallel surfaces with the two outer surfaces adapted to act as beam reflectors for internal light and the third surface in operation acting as a beam splitter and beam combiner, the optical block having an input portion by means of which an input beam of light to be analysed can be input so as partially to pass through said third surface to be internally reflected by one of said outer reflectors, and partially to be reflected by said third surface so as then to be internally reflected by the other of said outer reflectors whereby light internally reflected by said outer reflectors is combined at said third surface to produce an exit beam, and wherein said outer surfaces have an inclination with respect to one another and are asymmetric with respect to said third surface so as to generate in the exit beam a linear fringe field distributed about the zero-order fringe.

2. An optical block in accordance with claim 1 in which the exit beam results from the interference of the beams transmitted and reflected from the beam splitter/combiner

PENT COOPERATION TREA

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

Date of mailing (day/month/year) 21 June 2001 (21.06.01)	To: Commissioner US Department of Commerce United States Patent and Trademark Office, PCT 2011 South Clark Place Room CP2/5C24 Arlington, VA 22202 ETATS-UNIS D'AMERIQUE in its capacity as elected Office
International application No. PCT/GB00/02898	Applicant's or agent's file reference 5314399
International filing date (day/month/year) 27 July 2000 (27.07.00)	Priority date (day/month/year) 27 July 1999 (27.07.99)
Applicant JONES, Robert et al	

1. The designated Office is hereby notified of its election made:

 in the demand filed with the International Preliminary Examining Authority on:

27 February 2001 (27.02.01)

 in a notice effecting later election filed with the International Bureau on:

2. The election was was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

C

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No.: (41-22) 740.14.35	Authorized officer Juan Cruz Telephone No.: (41-22) 338.83.38
---	---